

# Evaluation of Chinese Raingun Py<sub>1</sub>-30 with Different Nozzle Sizes

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**ABSTRACT:** The Chinese raingun Py<sub>1</sub>-30 was installed and tested at NARC high efficiency irrigation systems sites, Islamabad. The diesel engine of 5 HP was mounted on a portable trolley. Various parameters such as distribution uniformity, area of coverage, wind speed effect and application rates were examined at different discharge and pressures for different nozzle sizes. Most sprinklers require co-efficient of uniformity of at least 80 percent. Christiansen's co-efficient of uniformity for nozzle sizes of 6 and 8.6 mm was higher than 80 percent which shows that nozzle size and operating pressure are correct combination for raingun Py<sub>1</sub>-30. The evaluation of parameters related to the raingun shows that system is effective for irrigation when wind speed is not more than 7 km/h.

**KEYWORDS:** Coefficient of Uniformity, Discharge, Pressure, Wind speed.

## INTRODUCTION

Sprinkler irrigation is a versatile means of applying water to the surface of any crop or soil. Sprinkler irrigation system has several advantages: (i) It may be adopted on porous soil for good distribution by surface methods; (ii) It is the only option for land having steep slopes and erodible soils; (iii) It is good for shallow soils, the topography of which prevents proper leveling; and (iv) Sprinklers have been adopted for many agricultural and non-agricultural uses. Some of these include water distribution for compaction. It can also be used for fire and frost protection. Different sizes of nozzle have been developed for Chinese raingun Py<sub>1</sub>-30. The uniformity of irrigation system is important for efficiency, yield and economics and is strongly affected by pressure, wind and nozzle sizes. Properly wetted area with the Py<sub>1</sub>-30 raingun shows uniform application. The amount of overlapping required to achieve a given uniformity of wetting depends on nozzle size, water pressure, operating characteristics of sprinkler and the wind speed. When distribution is perfect and every catch can receive the same amount of water, the value of co-efficient of uniformity (CU) will be 100 percent.

Low value of uniformity often indicates an incorrect combination of sprinkler nozzle sizes, operating pressure and spacing. Usually in the Chinese raingun Py<sub>1</sub>-30, different sizes of nozzle are developed to supply the irrigation requirements of the whole farm.

The objective of this study was to find the effectiveness of Chinese raingun Py<sub>1</sub>-30 for irrigation practices on the surface of the soil by evaluating different parameters. The effect of Christiansen's co-efficient of uniformity, statistical uniformity co-efficient, wind speed effect, area of coverage and application rates were examined at different and discharge pressures for different nozzle sizes.

## MATERIALS AND METHODS

As rainguns are a type of sprinkler irrigation system, it was possible to evaluate these using techniques already developed for that type of system. A 5 HP diesel engine, mounted on a portable hand move trolley was equipped with a high pressure, multistage pump with six impellers and located at the well of the NARC High Efficiency Irrigation System Site. A 6.09 mm reinforced rubber suction pipe with foot valve dipped into the well to deliver the water to the

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supply line. A 51 mm rubber pipe from the pump to the field outlet was used to supply the water to the raingun Py<sub>1</sub>-30. Male and female couplers were used to connect different length of pipes laid on the soil surface. The components parts were easily disconnected whenever required. The system was water tight when the pipes were under pressure.

The head of raingun with tripod and pegs was 1.34 m above ground level. The Py<sub>1</sub>-30 raingun has replaceable nozzle of different sizes. The 6 and 8.6 mm nozzles were tested in this study. The trajectory angle of the nozzles was 30 degree. A pressure gauge was fixed to the delivery side of the pump and one pressure gauge was fixed just below the head of the Py<sub>1</sub>-30 raingun to measure the pressure.

Four quadrants were laid out with the help of the magnetic compass needle. The direction of the quadrants were North-South and East-West. Eighteen catch cans were placed in each of the quadrant. The first catch can was placed one meter from the center of the raingun and thereafter at two meter intervals. Each catch can was set in an upright position with its top parallel to the ground. Surrounding vegetation was removed from all the sides of the catch cans. The volume of water in each catch can was measured with the help of a graduated cylinder.

Design of sprinkler system requires some knowledge of the performance of rotating sprinkler with respect to the uniformity of application. The function of the raingun Py<sub>1</sub>-30 is to distribute the water uniformly over the land without runoff and excessive drainage (i.e, deep percolation) from the root zone. Christiansen's co-efficient of uniformity was adopted for the assessment of the uniform distribution of water over the land because it is more related to the average depth in the lower half of the spread pattern than alternative procedures.

The irrigation system was operated for two hourly periods at 3.5, 4.2, 4.9, 5.6 bars of pressure head. Four sets of data were collected at each pressure head for 6 and 8.6 mm nozzle sizes. The amount of water caught in each collector was measured and Christiansen's co-efficient of uniformity was calculated by the following formula (Christiansen, 1942):

$$Cu = \left( 1 - \frac{\sum xi - \bar{x}}{n\bar{x}} \right) 100$$

where:

Cu = Christiansen's co-efficient of uniformity in percent;

xi = Individual collector amount (deviation from the mean);

$\bar{x}$  = Mean collector amount; and

n = number of collector measured.

Statistical co-efficient of uniformity (SCU), the weight values for the distribution of infiltrated depth (or applied water) may be a good measure for irrigation effectiveness. Statistical uniformity co-efficient (SCU) is calculated as:

$$SCU = \left[ 1.0 - \frac{\sum d^2}{(n-1)m^2} \right] 100$$

where:

d = The absolute value of the deviation of the individual observations of depth applied from the mean value m;

n = number of equally spaced collectors; and

m = Average of all the observations.

Application rates of different nozzle sizes are very important, when Py<sub>1</sub>-30 raingun works in the field. Application rate gives information whether the nozzle sizes properly match to the sprinkler head for the soil, crop and terrain on which they operate. The average application rate of an individual sprinkler can be calculated by the equation.

$$Ra = K \frac{Q}{A}$$

where:

Ra = Application rate (mm/h);

Q = Sprinkler discharge (litre/minute);

A = Wetted area of sprinkler (m<sup>2</sup>); and

K = Unit constant (k = 60.0)

## RESULTS AND DISCUSSION

### Effect of Operating Pressure on Uniformity with 6 mm Nozzle Size

The raingun was tested at 3.5, 4.2, 4.9, 5.6 bars, respectively. At these pressures, the raingun produced even irrigation over the whole of the wetted circle (Table 1).

At 3.5 bar pressure Christiansen's co-efficient of uniformity was 88.4 percent. Area of coverage was 530.9 m<sup>2</sup> and application rate was 4.9 mm/h. As pressure increases both CU and SCU decrease. That is why at 4.2 bar pressure the CU was 88.1 percent and SCU was 61.7 percent which is more than the 4.9 and 5.6 bar pressure. At 3.5 and 4.2 bar pressure head, nozzle size and trajectory angle produced a particular range of drop size. At these pressures, drop size distribution was more uniform. The results showed that the range of drop sizes can be controlled by the size of nozzle and the operating pressures.

At 4.9 bar, the CU was 81.3 percent and area of coverage was 907.9 m<sup>2</sup>, which is more than 5.6 bar pressure. At 5.6 bar the CU was 79.3 percent and area of coverage was 907.9 m<sup>2</sup>.

Table 1 shows that SCU decreases as pressure increases. For this particular raingun pressure from 3.5 to 5.6 bar normally increased the depth of water applied. Drop size also decreases by increasing pressure. Large drops are less affected by wind than small drops. As pressure increase, the initial velocity of the drops results in an

increased distance of flight as shown in Table 1 by the enlarged area of coverage.

### Application Rate with 6 mm Nozzle Size

At 3.5 bar, the application rate was 4.9 mm/h and area of coverage was 530.9 m<sup>2</sup>, which is greater than 4.2 bar. As pressure increases, wetted area of this raingun increases and application rate decreases as shown in Table 1. At pressure 4.2 bars wetted area was 706.9 m<sup>2</sup> and application rate was 4.07 mm/h, which is more than 4.9 and 5.6 bar. At this pressure, wetted area was 907.9 m<sup>2</sup> and application rate was 3.4 mm/h. These results show that pressure is inversely proportional to the application rate.

### Effect of Wind Speed with 6 mm Nozzle Size

Effect of wind speed was also analyzed for this particular raingun when pressure was constant. Rain from sprinkler is easily blown by wind and wind can distort wetting pattern and upset both the CU and SCU. To reduce the effect of wind, the sprinkler should be operated at early in the morning and in the evening hours. Vories and Van Bernuth (1980) reported that CU decreases as wind speed increases. Table 1 shows that wind speed greatly affected the values of both co-efficient of uniformities. Therefore, if the effect of wind speed is not considered in the design of a sprinkler irrigation system, the resulting system performance may be disturbed.

The raingun Py-30 of 8.6 mm nozzle size was also tested at 3.5, 4.2, 4.9 and 5.6 bar, respectively. The results are provided in Table 2.

Table 1: Mean Performance Characteristics at Different Pressure Heads for Nozzle Size 6 mm of Chinese Raingun Py<sub>1</sub>-30

Pressure (bar)	Discharge (l/s)	Discharge l/minute	Effective radius (m)	Coverage area (m <sup>2</sup> )	Christiansen's co-efficient (%)	Statistical uniformity co-efficient (%)	Wind Speed (km/h)	Application rate (mm/h)
3.5	0.724	28.4	13	530.9	88.4	68.1	11.2	4.9
4.2	0.80	48.0	15	707.0	88.1	61.7	7.0	4.0
4.9	0.86	51.6	17	907.9	81.3	37.53	6.1	3.4
5.6	0.92	55.0	17	907.9	79.3	37.6	5.6	3.6

Table 2: Mean Performance Characteristics at different Pressure Heads for Nozzle Size 8.6 mm of Chinese Raingun Py<sub>1</sub>-30

Pressure (bar)	Discharge (l/s)	Discharge l/minute	Effective radius (m)	Coverage area (m <sup>2</sup> )	Christiansen's co-efficient (%)	Statistical uniformity co-efficient (%)	Wind Speed (km/h)	Application rate (mm/h)
3.5	0.94	56.4	17	907.9	88.7	64.2	6.6	3.7
4.2	1.22	73.2	27	2290.2	75.91	41.0	14.3	1.9
4.9	1.92	115.2	27	2290.2	73.9	48.5	13.7	3.0
5.6	2.11	126.6	29	2642.0	89.5	57.96	6.0	2.8

### Effect of Operating Pressure on Uniformity with 8.6 mm Nozzle Size

At pressure of 3.5 bar, the CU was 88.7 percent and area of coverage was 97.9 m<sup>2</sup>, which is higher than 4.2 bar. As pressure increases, the wetted area of coverage increases but, uniformity decreases. At 4.2 bar the CU was 75.9 percent and area of coverage was 2290.2 m<sup>2</sup>, which was greater than the CU when the nozzle was operated with 4.9 bar pressure head. At 4.9 bar, the CU was 73.9 percent. At 5.6 bar exceptional results were obtained which showed CU of 89.49 percent and area of coverage of 2642.9 m<sup>2</sup>. This is because the wind speed was very low, and was blowing at 5.7 km/h (Table 2).

### Effect of Pressure on SCU with 8.6 mm Nozzle Size

Table 2 shows that when pressure increases from 3.5 to 5.6 bar, wetted area of coverage increases but, SCU decreases. However, exceptional results were obtained, when, wind speed was very low. At 5.6 bar, when wind speed was 5.7 km/h, the value of SCU was 57.4 percent.

If the pressure is substantially below 3.5 bar or above 5.6 bar for this particular raingun and nozzle size, the distribution of water can be quite different from that normally expected. If the pressure is too low from 3.5 bar, the water jet does not break up easily and most of water falls some distance from the sprinkler. Large water drops are produced which destroy the soil structure. If the pressure is too high more than 5.6 bar, jet breaks up to much causing misting. Most of water falls close to sprinkler. The value of uniformities therefore, decreases. For the nozzle size of 8.6 mm as pressure increases it decreases

the co-efficient of uniformities, because of greater sensitivity to wind drift. Water pressure increases the initial velocity of the drops resulting in an increased distance of flight as shown in Table 2 by the enlarged area of coverage.

### Application Rate with 8.6 mm Nozzle Size

At pressure 3.5 bar, the application rate was 3.72 mm/h and wetted area was 907.2 m<sup>2</sup>, which was greater than 4.2 bar. As pressure increases, wetted area of the raingun increases and application rate decreases, as show in Table 2.

At 4.2 bars, the wetted area of coverage was 2290.2 m<sup>2</sup> and application rate was 1.92 mm/h. The results with 4.9 bar were different because application rate was 3.0 mm/h. This is because coverage area was the same as in 4.2 bar but, the discharge in 4.9 bar was 1.92 l/s.

The application rate for 5.6 bar was 2.87 mm/h when the coverage area was 264.0 m<sup>2</sup>. The results show when pressure increases wetted coverage area increases and application rate decreases. Hence, pressure is inversely proportional to the application rate. Kay (1983) reported that increasing the nozzle size or pressure and bringing sprinkler close together would increase the application rate.

### Effect of Wind Speed on 8.6 mm Nozzle Size

For 8.6 mm nozzle size, at pressure 3.5 bar when wind speed was 4.6 km/h, the CU was 91.0 percent and at the same pressure when wind speed was 6.9 km/h, the CU was 87.6 percent. At pressure 4.2 bar when wind speed was 5.7 km/h, the CU was 83.3 percent and at the same pressure when wind speed was 23.8 km/h the CU was 64 percent. Therefore, when wind speed

increases the co-efficient of uniformity decreases. The results from this study show that SCU, values also decrease as wind speed increases.

## CONCLUSIONS

The data from this study show that Py<sub>1</sub>-30 raingun when operated at low pressure will lead to less sensitivity to wind speed and even distribution of water in the area. This raingun produces an acceptable range of drop size as nozzle size increase, the area of coverage increases. Nozzle size of 6 mm at 4.2 bar pressure provides high uniformity and area of coverage at wind speed of 7.0 km/h. Nozzle size of 8.6 mm at 5.6 bar pressure provides high uniformity and area of coverage with wind speed of 6 km/h. Rotation of raingun Py<sub>1</sub>-30 controls the water application rate.

For this raingun when nozzle size and pressure increases, the application rate also increases. But when pressure increases from 3.5 to 5.6 bar with each size of nozzle alongwith increased wetted area, the application rate decreases.

## REFERENCES

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